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SOLAR ENERGY POTENTIAL AND ITS DEVELOPMENT FOR SUSTAINABLE ENERGY GENERATION IN NIGERIA: A ROAD MAP TO ACHIEVING THIS FEAT

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ABSTRACT
The paper discusses the solar energy potential for sustainable energy generation in Nigeria, the numerous issues involved in harnessing solar energy and clearly articulates a road map to enable Nigeria tap into this huge potential. Research indicate that, Nigeria lying in the tropics, receives abundant sunshine where about 1500PJ (about 258 million barrels of oil equivalent) could be available to Nigeria annually from solar energy if solar appliances with 5% conversion efficiency were used over only one per cent of the total land area of the country for about six months of a year. Due to the numerous disadvantages of conventional fuel sources when compared with solar energy and the recent giant strides in improving solar cell efficiency using a photovoltaic (PV) device that converts 40.8% of light that hits it into electricity, Nigeria needs to reposition herself by investing in this invaluable resource to secure the energy future of our economy. This paper shows a road map that Nigeria and by extension any developing country can follow to achieve this feat.

KEYWORDS: Solar energy, Nigeria, road map, Renewable, Photovoltaic.

INTRODUCTION

The term "Renewable energy" covers all forms of energy generated from natural resources such as sunlight, wind, water (or hydro power), tide, geothermal heat, biomas and biofuels. They are derived from natural processes that are constantly replenished and each of them has characteristics that determine where and how they are used.

Several renewable energy projects in many countries have shown clearly that renewable energy can directly contribute to poverty alleviation by providing a substantial amount of energy needed for creating businesses and employment especially in rural communities that have not yet been connected to the National grid (Federal Ministry of Environment, 2013). Several renewable energy technologies are presently being used to supply energy for cooking, space heating, lighting, automobiles, etc. The combination of energy efficiency, conservation, and renewable energy resources, should allow Nigeria to meet any future increase in demand without increasing its reliance on non-renewable resources (Federal Ministry of Environment, 2013).

Solar energy can be seen as the anchor behind various forms of renewable energy. It anchors hydro power where the hydrological cycle is being controlled by the sun as well as Wind Power where the movement of air is due to the heating effect of the sun on the atmosphere. In general, heat, kinetic energy, electrical energy and chemical energy can be provided via solar energy conversion (Tyagi et al., 2013). In theory, solar energy can be perceived as an ideal energy source, because it is free and virtually limitless. However the technological barriers with regards to its collection, distribution and storage are great. Solar energy forms the basis or acts as the source of all other forms of energy on earth. Hence with the increase in intensity of solar radiation reaching the earth, it is paramount that this invaluable resource be put into adequate and efficient use in various areas of life. Solar energy utilization takes its root in the early ages when solar energy (sun) was used as a clock, as a compass, for preservation of food etc. In this modern age we have simply improved upon the findings of the old to get greater value, efficiency and time saving. To this end solar energy is ever growing and ever expanding in its utilization.

According to recent reports, the current photovoltaic (PV) cells installations are still small and provide only 0.1% of world total electricity generation even though PV cells installations are growing at 40% average annual rate (Tyagi et al., 2013). It has been predicted that PV cells will deliver about 345GW (around 4% of world total energy) by 2020 and 1081GW by the year 2030 (Tyagi et al., 2013). In Germany, PV produced 27.6TWh, while Wind produced 46TWh in 2012 (Bayar, 2013). Renewables in total accounted for 21.9 per cent of Germany's energy mix in 2012 out of which 4.6 per cent of total electricity production (which is a 47 per cent rise from the previous year) was from PV, 7.3 per cent was from Wind, biomass accounted for 5.8 per cent and hydropower made up 3.3 per cent (Bayar, 2013).

Germany presently leads the world in the number of PV installations (Tyagi et al., 2013). This feat has been achieved because they have developed and pursued their renewable energy generation and utilization plan which has helped largely in solving their energy demand issues. Nigeria needs to also look into our renewable energy potentials and begin on a journey to harness them as a supplement to other conventional energy sources. This

paper presents a plan to develop the capacity to harness our solar energy potential, showing pragmatic steps that Nigeria can follow to begin in this direction.

MATERIAL AND METHOD

This is a literature based conceptual paper. The authors reviewed literature on solar energy potential and issues surrounding their successful deployment and proceeded to develop a detailed road map of how this potential can be harnessed for sustainable energy generation in Nigeria. Numerous advantages that should serve as a stimulant to policy makers to both adopt and implement the plan are also provided.

NIGERIA AND OUR FAVOURABLE LOCATION

Nigeria, having a land mass of 923,768sq.km, is situated in the West African region and lies between longitudes 3 degrees and 14 degrees and latitudes 4 degrees and 140 degrees (Nigeria Embassy, 2013). Nigeria receives abundant sunshine all the year round being just above the equator. The sunshine duration averages 6.5 hours daily with an average flux of 5.55 kWh per square meter per day. This implies that Nigeria receives 4.851×10^{12} kWh of energy per day from the sun. The solar radiation intensities range from 3.5-7.0 kWh per square meter per day increasing from the South to the North (Oseni, 2012). This energy source could be available for 26% of the day (9.00am-4.00pm). These facts and figures regarding Nigeria's geographical location clearly indicate that the potential to generate significant amount of electrical energy from solar energy is very high for Nigeria. However, very little has been done in this direction as the government is yet to take pragmatic steps towards developing and implementing policies and plans that will serve as a base line on which solar energy utilization in Nigeria can thrive.

ELECTRICAL ENERGY GENERATION POTENTIAL FROM SOLAR ENERGY IN NIGERIA

The energy generated in Nigeria is grossly inadequate, hence the need to improve structures on ground, and also introduce alternative energy technologies (i.e. renewables) to complement current government efforts to provide sustainable energy for the citizens (Federal Ministry of Environment, 2013). Nigeria's present electricity supply is highly insufficient and epileptic; a situation which has led to individuals corporate and government organizations making alternative arrangements to provide electric power for their installations using various generators with a wide range of power capacity. No doubt, this has increased the cost of production and by direct consequence supports inflation and a lower standard of living of Nigerian Citizens. The additional cost these installed generators bring with their usage is that of environmental degradation which has become a major concern in our world today. Thinking "renewables" is therefore a general approach that has been identified to fill in this energy shortage without degrading our environment.

According to Nnaji and Unachukwe, (2010), Nigeria (lying in the tropics) receives abundant sunshine, where about 1500PJ (about 258 million barrels of oil equivalent) could be available annually from solar energy, if solar appliances with 5% conversion efficiency were used over only one per cent of the total land area of the country for about six months of a year. A giant feat recorded by some scientists at the United States energy department, National Renewable Energy Laboratory (NERL) in August 2008 set a world record in solar cell efficiency with a photovoltaic device that converts 40.8% of light that hits it into electricity (National Renewable Energy Laboratory, 2008; Tyagi et al., 2013). Higher PV cell efficiencies are still being pursued; hence the total land mass requirement will continue to be on the decrease. With this improvement in technology, Nigeria will therefore need a land mass smaller than 1% of its total landmass to get the required energy needed.

Oseni (2012) gave a detailed analysis of energy trends in Nigeria between the year 2007 and 2008. The author extensively presented ways of improving household access to electricity and energy consumption pattern in Nigeria with a focus on using renewable energy alternatives. According to the author, the country receives an average solar radiation at the levels of about $19.8 MJm^{-2}$ per day and average sunshine hours per day estimated at $6 hday^{-1}$. With an average solar radiation level of about 5.5kWh per day and the recent improvements in PV panel efficiencies, it is possible to generate 190550GWh of solar electricity per year with solar panels covering only 1% of the entire land mass of Nigeria (Oseni, 2012).

The energy demand in Nigeria will continue to increase as the Nigerian population continues to increase and as the energy demand per person increases due to fast urbanization. This means that the pressure on existing energy sources will continue to increase. Although Nigeria is known as a major producer of fossil fuel (which is a primary energy), a greater percentage of her secondary energy needs are supplied by expensive imports. According to Oseni (2012), Nigeria consumed 8.41 million tonnes of oil equivalent of petroleum products in 2007 with more than 93% of it imported where fossil fuel provided about 61.4% of the total indigenous primary energy production, with crude oil (49.9%) and natural gas (11.5%).

Although fossil fuels contributed immensely to indigenous production, they contributed only 17.8% to the total primary energy consumption in the country (Oseni, 2012). This is the case because most of the crude oil produced as primary energy resource is exported in their crude state. This situation has given Nigeria less value than what would have been available if the capacity to refine the abundant raw crude oil for consumption in the country was installed.

Presently in Nigerian refineries, the flaring of natural gas resulting in serious environmental issues is still the norm rather than the exception. A greater capacity to refine crude oil without addressing these issues will lead to further pollution of the environment, a situation that has dire impacts on citizens. It is therefore necessary that other alternatives be considered as supplements to crude oil so as to create an energy utilization balance for the Nigerian economy.

ISSUES OF SOLAR ENERGY UTILIZATION FOR GENERATING ELECTRICITY

Solar energy utilization for generating electricity no doubt has several advantages which include: low operational and

maintenance cost, a very high meantime between failures of about 20-30 years, noiseless and no moving parts during operation, availability of PV panels in different sizes or modules over a wide range of power rating, perceived environmental friendly nature with respect to release of greenhouse gases, global warming, ozone layer depletion, etc. However several issues arise in generating electricity from solar energy. These issues include:

Long Energy Pay-Back Time

Sherwani et al. (2010) carried out a review of the life cycle assessment of solar PV based electricity generation systems. According to their findings, the variation in the energy pay-back time (EPBT) and green house gas (GHG) emissions have been dependent upon many factors, such as the type of solar cell, solar panel orientation and angle, irradiation of the location, difference installation (integrated or non-integrated systems as well as facade, flat roof and solar roof tiles), efficiency of the Balance of system (BOS) components, size (capacity) of the system, lifetime of the system and the electricity mix of that particular country and year of study. The main issue that arises from this is that EPBT influences the decision of investors to invest in electrical energy generation using PV panels. If investors perceive the EPBT in solar PV based electricity generation systems to be too long, they may decide to seek for alternative investments which will hinder the growth of the Solar PV electricity generation Industry. It is therefore necessary that the energy pay-back time of solar PV based electricity generation systems be reduced considerable through continuous improvements in designs to facilitate production of PV cells that are cheaper and yet have higher efficiencies.

High Up Frontal Capital Cost

Another major down side of solar energy utilization in generating electricity is the high up frontal capital cost compared to its conventional energy alternatives (Chigbo, 2010). The general perception is that this technology is not yet mature hence it is only suited for particular markets and even then will require heavy subsidy to make it viable. This is quite erroneous to some degree as many countries such as Germany, the United States and China have succeeded with their solar energy utilization plans and are already enjoying the numerous dividends (Tyagi et al., 2013). Solar voltages have been powering space modules since the beginning of space programmes and talking about the cost, the high up frontal capital cost can be handled by letting Giant companies and Governments play a part in the programme by bringing in the much needed up front capital and recouping their investment over time.

Ignorance of the Benefits of the Technology

Another serious setback to the solar energy program is ignorance of the benefits of this technology. Awareness of the opportunities offered by solar energy and its technology is low among members of the public and private sector stakeholders. This lack of information and awareness creates a market distortion that results in higher risk perception for potential renewable energy projects. According to Kok et al. (2011), energy conservation interventions have frequently failed because they often did not take the full range of significant influences on human behaviour, into account. There is therefore a need for dissemination of information on solar energy resource availability, benefits and opportunities to the general public in order to raise public awareness and generate activities in the sector. Kenya has taken giant steps in the number of solar power systems installed per capital (but not the number of watts added). More than 30,000 very small solar panels are sold in Kenya annually, as more Kenyans adopt solar power every year than they make connections to local grid.

Requirement of Large Expanse of Land.

Another major issue in the use of solar PV panels is the large expanse of land required for their installation. Clearly, moving to solar energy as a major energy producer would mean an enormous reallocation of land and resource use. However with the continuous improvement in PV efficiencies, the required space per Kwh of electricity generated will continue to be on the decrease.

Low efficiencies of PV panels.

Low efficiency of PV panels is another draw draw-back presently limiting the widespread diffusion and usage of PV cells in generating electricity. PV panel efficiencies must be increased to establish their acceptance in the energy market. Table 1 shows some materials used for making PV panels and their efficiencies. It can be seen from the table that GaAs cells which uses multi-junction cells have the highest efficiencies so far. It is believed that exploiting the multi junction technology will provide the future PV panels with higher efficiencies. PV panel efficiencies and output power decreases due to increase in temperatures hence the need to provide cooling at high illumination conditions. Dust and humidity also reduce the efficiencies of solar PV cells to lower values.

Table 1: PV panel materials and their efficiencies

PV panel material	Present Average Efficiency (%)	Remark
Monocrystalline Silicon Solar Cell	28	Available Commercially
Polycrystalline Solar Cell	19.8	Commercial efficiencies are about between 12 and 15%
GaAs Cells (often mixed with other metals as alloys)	40.7	Highest efficiency so far
Dye-sensitized and organic base cells	5.4	Lowest efficiency
Thin film technology	19.9	Available Commercially
Hot carrier solar cell	66	Has never been commercialised but remains an experimental technology due to lack of suitable material that can decrease carrier cooling rates

Note: data extracted from the review carried out by (Tyagi et al, 2013).

Solar Irradiation

Solar irradiation which varies throughout the entire day and affects the efficiency and output of PV cells is another issue being considered in using solar cells. Increase in solar irradiance increases the PV module efficiency because the high number of photons hitting the module increases and many electron-hole pairs are formed which will produce more current. During the night, solar irradiation is zero hence PV cells will have zero output at night. A simple way to solve this problem is to incorporate another renewable energy source such as wind energy with the solar PV modules so that they will deliver the required power at night. Electricity storage in batteries is also useful to make electrical energy available during these periods when solar irradiation is low or not available.

Environmental Pollution

Although solar PV cells are generally acclaimed to be environment friendly, their by-products during the manufacturing process and waste after their useful life can also constitute environmental hazards. Raw materials for making solar PV cells are obtained through mining operations which may cause danger to miners. In addition, mining machines involve usage of fossil fuels such as petrol and diesel which also cause environmental pollution through emission of hazardous gases and heavy metal from the mines. As more PV cells are manufactured and installed, the environmental pollution which results through their manufacturing process and disposal after their useful life will also be on the increase.

Long life storage and long distance transportation (Goffman, 2008).

The problem of storing large amount of solar energy after it has been converted to electrical energy is a huge challenge yet to be overcome before solar energy becomes a major contributor to the world energy grid. A major infrastructure investment will be necessary for such a storage system to be possible. Also, transporting the energy from where it is produced to where it is needed is another huge challenge to be overcome. A new high-voltage, direct-current (HVDC) power transmission backbone would have to be built using Direct Current for this to be possible.

ROAD MAP TO HARNESS SOLAR ENERGY FOR SUSTAINABLE ELECTRICAL ENERGY GENERATION IN NIGERIA.

A major draw-back which most developing countries in Africa (including Nigeria) have is the lack of will and commitment to invest in developing and sustaining our indigenous technologies. We often opt for the short run solutions of purchasing finished goods and services while neglecting the seemingly hard way of developing the necessary technologies so as to use our abundant locally available raw materials to produce these goods and services ourselves. This has continued to put us behind as third world nations, a situation that will become worse if we do not begin to do things differently.

It has been recognized by all stakeholders that the major barrier to renewable energy and energy efficiency development in Nigeria is Lack of Policy and Legislation (Federal Ministry of Environment, 2013). This lack of policy and legislation on renewable energy technologies and also the need to address the inefficient use of energy has been identified as key barriers to the development of the sector.

The Authors present a four stage pragmatic plan that will help Nigeria to harness her abundant solar energy as a means of providing sustainable electrical energy generation in Nigeria. This plan can serve as a vital document to build on in the development of the renewable energy policy for Nigeria. The four stages described in the plan are

1. Solar PV Panel Technology Development Stage
2. Solar/Wind Power Plant Development Stage
3. Commercialization Stage
4. Evaluation , Adjustment and Expansion Stage

These stages which are overlapping in some cases are described in details in the following sub sections.

Solar PV Panel Technology Development Stage

This stage involves the acquisition of the necessary infrastructure, equipment and facilities, engaging skilled personnel, training and re-training and development of Nigerian Photo Voltaic (PV) Panels which will be used in the Solar / Wind Plants to be developed.

The Authors propose that the Nigerian Government should establish a Solar PV Panel Development Centre (SPVPDC) in one of the Northern or middle belt States of the federation. Developing this technology without any collaboration will be a hard way to start hence, the Government will have to sign contractual agreements (at least 10 years) with at least two proven Solar panels, cells and wafers manufacturers (such as Sungen Solar, Trina Solar, Yingli Green Energy and Suntech Power Holdings in China, Sharp in Japan, Hanwha SolarOne in South Korea) and their respective governments to facilitate collaborations with their experts who will at the beginning form the bulk of the skilled personnel in the Centre. They will be saddled with the responsibility of helping the Nigerian Government acquire the necessary infrastructure and equipment, training Nigerians and subsequently assisting in developing this Nigerian made PV panels. China is presently leading in solar PV production while European countries are leading in PV installation (Tyagi et al., 2013). China has taken the lead due to their government policies which provides subsidies to PV panel producers in China so as to give them comparative advantages over those produced in other countries in Europe, America, etc. This initiative has threatened the survival of PV producers in Europe and America (Bilby and Zhu, 2013; Young, 2013).

However, if talks with these giant solar companies fail to yield positive results, the government can collaborate with smaller companies in these same countries who have not yet made a strong impression on the world solar PV market. These Companies will be more willing to enter the agreement if they are presented with the numerous benefits they stand to gain through the collaboration (large market in Nigeria and other African countries for their product, protection from stifling bureaucracies that makes doing business difficult and rebates in taxes charged on their products before Nigerian PV panels are developed

and continuity in using a percentage of their product even after Nigerian PV panels have been developed).

The necessary facilities and equipment for the centre will be acquired with the support and collaboration of these professionals, Companies and Governments. The cost will definitely be high but it is one of the prices we have to pay now if we must break away from the circle of purchasing finished goods and services. The Innoson Vehicle Manufacturing Company (IVM) in collaboration with foreign skilled personnel from China, Japan and Germany has made indigenous cars (IVM, 2013). If they have succeeded with using this model, the authors believe that the Nigerian government can do the same if not better.

The centre is not to work in isolation but will collaborate with Tertiary Institutions all over Nigeria. Those to be trained in the Centre will be harnessed from different Tertiary Institutions in the country after a rigorous test and screening exercise to determine those who have the basic practical and theoretical knowledge needed to proceed with the training. However anyone irrespective of educational background who shows a high degree of technical know-how which is related and relevant to this area of research should also is considered for further training at the centre.

Training modules for long and short term theoretical and practical hands on based courses will be developed for use in the centre. Selected outstanding training participants will be retained in the centre after they complete their courses for further training and participation in developing Nigerian made PV panels. Funds especially grants will be available for those in the Centre to proceed with research ideas to achieve this feat. The Skilled personnel engaged will be saddled with most of the training responsibilities as contained in the contractual agreements which they would have already signed. Having acquired the necessary equipment and infrastructure, proceeding with developing Nigerian PV panels will be a possibility.

Researchers in Tertiary Institutions will also be given the privilege to report their research findings related to PV technologies to the Centre and grant awards and other forms of rewards will be made available to such researchers so that they can further develop their findings in collaboration with the Centre. Original proposals will also be dully considered from researchers to ascertain if they have the potential to result in ground breaking inventions before they are funded in collaboration with the centre.

The government will also need to pursue policies to attract Companies that already manufacture PV panels into the country. This is necessary to enable ease of transfer of research findings into finished products by appropriate collaborations of the Centre and Tertiary Institutions with these companies. These Collaborations will also provide a platform where these companies are willing and committed to funding research in this centre. At the beginning, the centre can work in collaboration with these companies in their countries before they finally set up their branch in the country. One of the incentives to encourage them to establish their branch in the country will be the second and third stage of this pragmatic plan where their PV modules will be used to develop Solar and Wind Power Plants and the subsequent commercialization involving small Power companies using Solar technologies which will place their products in high demand.

Solar/Wind Power Plant (SWPP) Development Stage

Solar energy is available for less than twelve hours in a day hence the need to store it for use when it is not available. However several researches have shown that combining solar energy and wind for electrical energy generation will result in harnessing two useful renewable energy resources in a complimentary way (Dihrab and Sopian, 2010). Solar energy will be readily available during the day while wind energy will be very useful at night.

The Centre (in collaboration with the Nigerian Society of Engineers, Council for the Regulation of Engineering in Nigeria (COREN), Tertiary Institutions and Indigenous Companies which may or may not have collaborations with Foreign Companies) will set up a research team saddled with the responsibility to develop Nigerian Solar/ Wind Power plants of various units and specifications. This technology is already available here in several Tertiary Institutions here in Nigeria. There is however the need to upgrade it to international standards so that the Power plants developed will meet certain minimum criteria and be accepted in other markets outside Nigeria. Through appropriate government policies, Companies which produce high capacity batteries and inverters will also be encouraged to set up branches in the country in preparation for the mass deployment of these SWPP in a commercial scale. Indigenous companies will be given some advantages in terms of tax rebates, protection from stifling bureaucracies, etc. over those who chose to manufacture their products outside the country. Appropriate agreements should also be signed with these companies assuring them of the large scale use of their products made in the country along with the SWPP developed. Their products must however meet laid down criteria.

This stage can begin side by side with the development of Nigerian PV panels with already available panels but as a matter of laid down policies, a greater percentage of these panels will be replaced by Nigerian made panels as the centre makes progress in their development.

Commercialization Stage

In this stage, Indigenous Power Companies which provide power, using the developed indigenous Solar/wind power plants are to be licenced having met minimum requirements and signed the necessary contractual agreements with the Government. These Companies are to be independent from Power Holding Company of Nigeria (PHCN) and given the right to install small, medium and large scale SWPP units directly in homes, offices, cottage companies, etc. They will determine their charge rates and Nigerians will have the right to choose between them and PHCN. The competition provided by PHCN will force their prices down to moderate values.

The German government developed a feed-in tariff (FiT) support offered by the Renewable Energy Sources Act (EEG) which has enabled dramatic expansion of renewable power coupled with significant cost reductions (Bayar, 2013). The government of Nigeria should develop a similar initiative to encourage energy users to opt for

solar alternatives. To offset the high initial investment cost of Solar PV panels, the Federal government will sign agreements with these companies to provide part of the initial investment funds which these companies will pay back through an agreed period of time. Since the maintenance cost is low, these companies will be able to pay-off their government support fund and will continue to sustain themselves in business.

Appropriate Government policies must be put in place for these Power companies to install their PV panels which require large space and their protection from vandalism. Nigerian Electricity Regulatory Commission (NERC) will provide visible government support to these companies so as to avoid resistance and other challenges which will hinder speedy development. China has proven that this protection is necessary, hence Nigeria can learn from their experience.

All established institutions (both public and private) should be given a platform to participate in educating Nigerians of the numerous and potential benefits of solar energy as an alternative to the conventional sources. The media (both electronic and print) should be used as a tool to educate Nigerians of the numerous benefits accepting solar energy alternative has not just for them as individuals but for the world in general. This is necessary to avoid the unwillingness of the general public to accept the new trend or make the necessary changes to their power installations. The incentives introduced by the government should be projected so that Nigerians can see their potential benefits and opt to enjoy them.

Evaluation, Adjustment and Expansion Stage

This stage involves evaluation of the progress made and making decisions of the necessary adjustments to correct the weaknesses identified in the plan and to strengthen procedures and processes already yielding positive results. It also includes expansion of the plan to develop other technologies that produce raw materials for making PV cells.

A feedback mechanism or structure must be put in place to allow proper evaluation of progress. A unit in the SPVPDC that is completely autonomous and free from the stifling bureaucracy of the other operations in the centre will coordinate this process. They will monitor the plans and ascertain their implementation in line with the stated objectives. They will, in collaboration with other stake holders involved in the plan, identify deviations from the proposed plan and the obvious reasons for such deviations. They will also be saddled with the responsibility of developing pragmatic solutions to overcome such challenges.

This stage will also pursue the development of other basic technologies that serve as raw material producers for the centre. This will include establishment of companies that develop silicon wafers for making, transistors, diodes, Integrated circuits (ICs) and PV cells. Development of Microelectronics and embedded systems technologies and other base technologies involved in production of PV panels will also be pursued during this stage. This will provide the necessary raw materials needed at the centre indigenously so as to further reduce the production cost while increasing the overall benefits associated with the establishment of these base industries that use these technologies.

CONCLUSIONS AND POLICY IMPLICATIONS

In this paper, the authors have shown Nigeria's solar energy potential and proceeded to consider the issues surrounding their deployment. A road map to follow showing pragmatic steps that will help Nigeria to develop our solar energy potential has been presented. No doubt, several plans have been developed by several governments in Nigeria but the problem has always been with the implementation. The authors believe that beginning to tackle our renewable energy issues by taking pragmatic steps towards implementing developed plans such as the one presented in this paper will take Nigeria out of the circle of a consuming economy to a creating one.

If this plan is pursued and implemented, the following are some of the numerous benefits it will bring to Nigeria.

- Development of Nigerian made PV panels which will contribute to the Nations GDP and GNI. This will be the natural consequence since these panels will be exported and foreign exchange will flow into Nigeria's economy. The African market will be a major target for the PV cells.
- Patenting of new Solar PV products developed in the Centre and other collaborating Institutions. As the PV panels are being developed, other products used along with it will also be developed indigenously and both the PV panels and these by products will bring up the number of patents registered for Nigeria.
- Human capacity building of those directly or indirectly involved with the project. This is one of the greatest advantages this plan will bring in for Nigeria. Human capacity building of those involved directly in the project will stimulate an avalanche of technological know how which will be required to both develop newer technologies and maintain the existing ones.
- Emergence of PV technology clusters and hubs in Nigeria which will stimulate Industrial growth through establishment of new firms (SMEs) that produce and market Solar PV panels.
- Publications on Solar PV research findings by those involved in the project.
- Provision of a base for further Industrial and International collaborations in Solar PV panels technologies. This will include the initial collaborations involved in the plan and subsequent ones that will be facilitated as the project expands.
- Provision of numerous direct and indirect employment opportunities for Nigerians. This will help to ameliorate, in no small measure, the present problem of unemployment which is one of the major challenges the Nigerian government has to tackle.
- Provision of a step towards moving our economy from consuming to creating. As Nigeria aspires to become a giant economy, we must be positioned to create finished goods and services from available raw materials to remain competitive in the scheme of things. Resource poor countries like Germany have shown the world that possessing the technology to transform imported raw materials to finished goods

can serve as an economy booster in any nation. Developing the technology capacity to both harness and maintain our renewable energy resources will therefore kick start Nigeria in this direction with respect to renewable energy.

- Provision of a practical platform to harness renewable energy resources in Nigeria with all the attendant advantages it provides over fossil fuel.
- Provide Nigeria with the possibility to commercialise usage of solar/ wind energy resources and a healthy competition to PHCN.

Nations like India, China, South Korea, Brazil, etc. have shown the world that pursuing a pragmatic plan can help any nation to change status from a consuming to a creating economy. The Indian government in demonstrating their seriousness in electricity production from solar energy and other renewable energy sources has setup a national solar mission to make India a leader in solar energy with a target for 500 GW power production through solar energy by 2030 (Tyagi et al., 2013, Nixon et al, 2010). They have developed and are following their solar energy plan ever since.

Although Nigeria does not presently have a renewable energy policy, this plan can help us to begin in this direction. Until we commit to doing things differently by summoning the will to both develop and pursue a pragmatic plan such as the one proposed in this paper, the necessary infrastructures and equipment will never be acquired, the skilled personnel to both harness, develop and maintain our renewable energy resources and technologies will not emerge, the right investors will not be attracted into the country and our economy will remain stagnated as a consuming one. The time Nigeria needs to begin is now.

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REFERENCES

Bayar T. (2013). "Germany Must Manage Growth and Costs of Renewable Power, IEA says" Renewable Energy World.com. Retrieved 03/06/2013 at http://www.renewableenergyworld.com/rea/news/article/2013/05/germany-must-manage-growth-and-costs-of-renewable-power-iea-says?cmpid=SolarNL-Thursday-May30-2013

Bilby E. and Zhu C. (2013) "UPDATE 2-EU denies breakdown in solar panel talks" REUTERS. Retrieved 3/06/2013 at http://www.reuters.com/article/2013/05/24/eu-china- solar-idUSL6N0E503U20130524

Britanica (2013) "Nigeria". Britanica Encyclopedia. Retrieved 13/06/13 at http://www.britannica.com /EBchecked /topic /414840/Nigeria#toc55281

Chigbo A. M., (2010). "The need to embrace Renewable energy technologies in Nigeria". Nigeria Journal of Solar Energy. Vol 21 pp 182-186

Dihrab, S. S and Sopian K. (2010). "Electricity generation of hybrid PV/wind systems in Iraq" Renewable Energy 35 (2010) 1303–1307

Federal Ministry of Environment (2013) "Renewable Energy" Federal Ministry of Environment. Retrieved 10/08/13 at http://environment.gov.ng/special-units/renewable-energy/

Goffman E. (2008) "Why not the sun? Advantages of and Problems with Solar energy" Proquest Discovery Guides. Retrieved 10/08/13 at *www.csa.com/discoveryguides/solar/review.pdf*

IVM, (2013) "INNOSON VEHICLE MANUFACTURING CO. LTD" Innoson Vehicle Manufacturing Co. Ltd. Retrieved 03/06/2013 at http://www.innosongroup.com/innosonmotors/about_us.php#

Kok G., Lo S. H., Peters G. Y. and Ruiter R. A. C. (2011) "Changing energy-related behavior: An Intervention Mapping approach" Energy Policy 39 (2011) 5280 –5286

National Renewable Energy Laboratory (2008) "NREL Solar Cell Sets World Efficiency Record at 40.8 Percent" National Renewable Energy Laboratory, US department of Energy. Retrieved 12/06/13 at http://www.nrel.gov/news/press/2008/625.html

Nigeria Embassy (2013) "About Nigeria" Embassy of the Federal Republic of Nigeria. Washington D.C. Retrieved 8/08/13 at http://www.nigeriaembassyusa.org/index.php?page=about-nigeria

Nixon J.D., Dey P. K. and Davies P.A (2010) "Which is the best solar thermal collection technology for electricity generation in north-west India? Evaluation of options using the analytical hierarchy process" Energy 35 (2010) 5230-5240

Nnaji and Unachukwue (2010) "Energy efficiency and the Nigerian economy: The need for an integrated approach". Nigerian Journal of Solar Energy, Vol21 pp179-181

Oseni M.O. (2012) "Improving households' access to electricity and energy consumption pattern in Nigeria: Renewable energy alternative". Renewable and Sustainable Energy Reviews 16 (2012) 3967–3974

Sherwani, A. F., J.A. Usmani, J.A. and Varun (2010) "Life cycle assessment of solar PV based electricity generation systems: A review" Renewable and Sustainable Energy Reviews 14 (2010) 540–544

Tyagi V.V., Rahim A. A. N, Rahim N.A., and Selvaraj J. A/L. (2013) Progress in solar PV technology: Research and achievement. Renewable and Sustainable Energy Reviews 20 (2013) 443–461

Young D. (2013) "EU, China Try to Talk Solar" Renewable Energy World.com. Retrieved 03/06/2013 at http://www.renewableenergyworld.com/rea/blog/post/2013/05/eu-china-try-to-talk-solar?cmpid=SolarNL-Thursday-May30-2013.